8 PRACTICAL CONSIDERATIONS FOR WETLAND IDENTIFICATION AND BOUNDARY DELINEATION

R. W. Tiner

ABSTRACT

Since the 1970s, the federal government in the United States has been increasingly more active in regulating construction in wetlands. During this time many states have similarly developed programs to control development in wetlands. These regulations have necessitated the establishment of standardized procedures to identify and delineate wetlands. These methods utilize one or more types of wetland indicators, including hydrophytic vegetation, hydric soils, and other indicators of periodic wetness associated with wetlands. Several methods have been used for wetland identification: (1) vegetation-based methods, (2) soil-based methods, (3) three-parameter methods (using plants, soils, and other signs of wetland hydrology), and (4) the primary indicators method (relying on unique features to indicate wetlands). This article reviews wetland indicators and how they have been used in these methods to identify and delineate wetlands. Wetland mapping is also discussed. Recommendations are offered on how to improve identification of wetlands for regulatory purposes.

Since the 1960s and 1970s, wetlands have received increased attention in the United States due to the passage of wetland laws by numerous states and enactment of the Federal Clean Water Act and amendments. These laws and their accompanying regulations have placed certain restrictions on the use of wetlands on both private property and public lands. For the first time, it became important to establish the boundaries or limits of wetlands on a piece of ground to determine the areal extent of government jurisdiction. In effect, these laws created a type of land use zoning program where permitted activities and exempted activities were allowed, and other uses were not. The purpose of these laws was either to protect wetlands from destructive projects that could be constructed on less environmentally

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harmful sites or to regulate certain uses of wetlands that would adversely affect the quality of the nation's waters. The former was largely the intent of state wetland laws, while the latter was a primary goal of the Federal Clean Water Act. Different approaches were developed to identify wetlands and their boundaries for these laws. The purpose of this chapter is to generally discuss these methods and to recommend some practical approaches for identifying and delineating wetlands.*

WHAT IS A WETLAND?

Wetlands encompass a wide array of "wet lands" called marshes, bogs, swamps, fens, pocosins, wet meadows, and other names. The diversity of wetlands is further evidenced by the number of definitions that have been developed for wetland inventories and for various laws and regulations. Wetland definitions for conducting wetland inventories are scientifically based, since these surveys aim to identify wet habitats. Legal definitions are grounded in scientific concepts, but may be broader or narrower depending on the interests to be protected or regulated.

From a legal standpoint, a wetland is whatever the law says it is. This has led some people to suggest that the definition of "wetland" is simply a policy question to be decided by politicians and administrators rather than by scientists (Kusler, 1992). Others argue that the definition of a wetland is a scientific question since, for example, identification of wetlands is largely based on analyzing vegetation, soils, and/or hydrology and requires training in biological and physical sciences; also, scientists and not politicians or administrators discovered functions of wetlands that are now highly valued by society. Once the universe of wetlands is defined by scientists, the role of politicians and administrators is to decide how best to regulate such areas to satisfy society's needs and interests. The foundation of all legal definitions of recent origin comes from scientific studies of marshes, swamps, and similar areas that have documented significant functions important to society. These studies have helped change society's view of wetlands from that of a wasteland to one of a valuable natural resource. Ecologists, botanists, biologists, and other concerned scientists undoubtedly assembled the necessary information to draft legal wetland definitions and, in most cases, actually wrote these definitions.

Despite differences in the actual wording of various wetland definitions, they have much in common (see Table 1 for examples). Most wetland definitions emphasize the presence and predominance of plants (hydrophytes) that grow in water or in periodically flooded or saturated soils. Some wetland definitions also include nonvegetated areas such as mudflats, rocky shores along the coast, and ponds (see U.S. Fish and Wildlife Service definition in Table 1), while others

* At the request of the U.S. federal government, the National Academy of Sciences established a Committee on Characterization of Wetlands in late 1993 to review the scientific basis for wetland delineation. They have reviewed existing wetland delineation manuals and procedures and presented their findings and recommendations in a report: *Wetlands: Characteristics and Boundaries* (1995).

Table 1 Definitions of "Wetland" According to Selected Federal Agencies and State Statutes

Organization (reference)	Wetland definition
U.S. Fish and Wildlife Service (Cowardin *et al.*, 1979)	"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."
U.S. Army Corps of Engineers (Federal Register, July 19, 1977) and U.S. Environmental Protection Agency (Federal Register, December 24, 1980)	Wetlands are "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas."
U.S.D.A. Soil Conservation Service (National Food Security Act Manual, 1988	"Wetlands are defined as areas that have a predominance of hydric soils and that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions, except lands in Alaska identified as having a high potential for agricultural development and a predominance of permafrost soils."
State of Rhode Island Coastal Resources Mgmt. Council (RI Coastal Resources Mgmt. Program as amended June 28, 1983)	"Coastal wetlands include salt marshes and freshwater or brackish wetlands contiguous to salt marshes. Areas of open water within coastal wetlands are considered a part of the wetland. Salt marshes are areas regularly inundated by salt water through either natural or artificial water courses and where one or more of the following species predominate:" (8 indicator plants listed). "Contiguous and associated freshwater or brackish marshes are those where one or more of the following species predominate:" (9 indicator plants listed).
State of Rhode Island Dept. of Environmental Mgmt. (RI General Law, Sections 2-1-18 *et seq.*)	Fresh water wetlands are defined to include, "but not be limited to marshes; swamps; bogs; ponds; river and stream flood plains and banks; areas subject to flooding or storm flowage; emergent and submergent plant communities in any body of fresh water including rivers and streams and that area of land within fifty feet (50') of the edge of any bog, marsh, swamp, or pond." Various wetland types are further defined on the basis of hydrology and indicator plants, including bog (15 types of indicator plants), marsh (21 types of plants), and swamp (24 types of indicator plants plus marsh plants).
State of New Jersey (NJ Pinelands Comprehensive Management Plan, 1980; Pinelands Protection Act - NJ STAT. ANN. Section 13:18-1 to 13:29.)	"Wetlands are those lands which are inundated or saturated by water at a magnitude, duration and frequency sufficient to support the growth of hydrophytes. Wetlands include lands with poorly drained or very poorly drained soils as designated by the

Table 1 Definitions of "Wetland" According to Selected Federal Agencies and State Statutes (continued)

Organization (reference)	Wetland definition
	National Cooperative Soils Survey of the Soil Conservation Service of the United States Department of Agriculture. Wetlands include coastal wetlands and inland wetlands, including submerged lands." "Coastal wetlands are banks, low-lying marshes, meadows, flats, and other lowlands subject to tidal inundation which support or are capable of supporting one or more of the following plants:" (29 plants are listed.) "Inland wetlands" are defined as including, but not limited to, Atlantic white cedar swamps (15 plants listed), hardwood swamps (19 plants specified), pitch pine lowlands (10 plants listed), bogs (12 plants identified), inland marshes (6 groups of plants listed), lakes and ponds, and rivers and streams.
State of New Jersey (Coastal Wetland Protection Act-NJ STAT ANN. Section 13:9A-1 to 13:9A-10)	"Coastal wetlands" are "any bank, marsh, swamp, meadow, flat or other low land subject to tidal action in the Delaware Bay and Delaware River, Raritan Bay, Sandy Hook Bay, Shrewsbury River including Navesink River, Shark River, and the coastal inland waterways extending southerly from Manasquan Inlet to Cape May Harbor, or at any inlet, estuary or those areas now or formerly connected to tidal whose surface is at or below an elevation of 1 foot above local extreme high water, and upon which may grow or is capable of growing some, but not necessarily all, of the following:" (19 plants are listed.) Coastal wetlands exclude "any land or real property subject to the jurisdiction of the Hackensack Meadowlands Development Commission...."
State of Connecticut (CT General Statutes, Sections 22a–36 to 45, inclusive, 1972, 1987)	"Wetlands mean land, including submerged land, which consists of any of the soil types designated as poorly drained, very poorly drained, alluvial, and floodplain by the National Cooperative Soils Survey, as may be amended from time to time, of the Soil Conservation Service of the United States Department of Agriculture. Watercourses are defined as rivers, streams, brooks, waterways, lakes, ponds, marshes, swamps, bogs, and all other bodies of water, natural or artificial, public or private."
State of Connecticut (CT General Statutes, Sections 22a–28 to 35, inclusive 1969)	"Wetlands are those areas which border on or lie beneath tidal waters, such as, but not limited to banks, bogs, salt marshes, swamps, meadows, flats or other low lands subject to tidal action, including those areas now or formerly connected to tidal waters, and whose surface is at or below an elevation of one foot above local extreme high water."

include deepwater habitats, such as lakes, as wetlands (see New Jersey Pinelands Protection Act definition in Table 1). Deepwater habitats may have been included because a state wanted to regulate alternative uses of water bodies and saw the wetland bill as a convenient opportunity to safeguard these important habitats. After all, many wetlands are inextricably linked to a permanent water body.

Despite the inclusion of deepwater habitats in some definitions for vegetated wetlands, there is much commonality in the definitions.

INDICATORS OF VEGETATED WETLANDS

Many wetlands are dominated by plant species that grow only in wetlands. These species, called "obligate hydrophytes", are the best vegetative indicators of wetlands. These wetlands are readily identified by their flora. The average citizen can usually recognize these types of wetlands without much training. Many wetlands, however, lack the presence of these species and cannot be simply identified as wetlands by vegetation alone. They can be recognized by soil properties characteristic of wetlands. Thus, plants and/or soils are typically the most useful indicators of wetlands. These features are usually most applicable in situations where drainage has not been improved to effectively drain former wetlands. In these altered conditions, an evaluation of the effect of drainage must be performed to establish the absence or presence of wetland for regulatory purposes.

Hydrophytic Vegetation Indicators

Hydrophytes are plants that grow, or are capable of growing, in water or on a substrate that is periodically anaerobic (oxygen deficient) due to excessive water content (Tiner, 1991a). It is the presence of these plants that has been traditionally used to identify wetlands. Such plants have adapted physiologically and/or morphologically, or in other ways, to survive in and successfully colonize these water-stressed environments. Table 2 lists some mechanisms by which plants have successfully acclimated to these conditions. For reviews of these mechanisms, see Blom and others (1990), Crawford (1983), Gill (1970), Hook (1984), Hook and Scholtens (1978), Hook and others (1988), Jackson and Drew (1984), Kozlowski (1984), Teskey and Hinckley (1978), and Whitlow and Harris (1979). A response of a plant to flooding may be quite different than its response to waterlogging. Hosner (1958) found red ash (*Fraxinus pennsylvanica*) to be more tolerant of flooding than eastern cottonwood (*Populus deltoides*), but he subsequently found the latter species to be more tolerant of soil saturation (Hosner, 1958). This clearly demonstrates that caution must be exercised when extrapolating results of flood tolerance studies to conclude that one species is more water tolerant that another. Moreover, this is further complicated by the likely occurrence within a given species of distinct populations with genotypic or phenotypic differences in flood tolerance, as reported by Gill (1970), Keeley (1979), and Crawford and Tyler (1969).

Wetland plant communities have been called "hydrophytic vegetation" for identifying regulated wetlands (Environmental Laboratory, 1987; Sipple, 1988; Federal Interagency Committee for Wetland Delineation, 1989). A review of wetland definitions in Table 1 finds that some definitions include a list of plants that are examples of hydrophytes, whose presence should indicate wetland. If the

Table 2 Plant Adaptations or Responses to Flooding and Waterlogging

Morphological adaptations/responses	Other adaptations/responses
Stem hypertrophy (e.g., buttressed tree trunks)	Seed germination under water
Large air-filled cavities in center (stele) of roots and stems	Viviparous seeds
Aerenchyma tissue in roots and other plant parts	Root regeneration (e.g., adventitious roots)
Hollow stems	Growth dormancy (during flooding)
Shallow root systems	Elongation of stem or petioles
Adventitious roots	Root elongation
Pneumatophores (e.g., cypress knees)	Additional cell wall structures in epidermis or cortex
Swollen, loosely packed root nodules	Root mycorrhizae near upper soil surface
Lignification and suberization (thickening) of root	Expansion of coleoptiles (in grasses)
Soil water roots	Change in direction of root or stem growth (horizontal or upward)
Succulent roots	Long-lived seeds
Aerial root-tips	Breaking of dormancy of stem buds (may produce multiple stems or trunks)
Hypertrophied (enlarged) lenticels	
Relatively pervious cambium (in woody species)	
Heterophylly (e.g., submerged vs. emergent leaves on same plant)	
Succulent leaves	
Physiological adaptations/responses	
Transport of oxygen to roots from lenticels and/or leaves (as often evidenced by oxidized rhizospheres)	
Anaerobic respiration	
Increased ethylene production	
Reduction of nitrate to nitrous oxide and nitrogen gas	
Malate production and accumulation	
Reoxidation of NADH	
Metabolic adaptations	

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plant lists were presented in this table, anyone familiar with plant ecology would recognize some species that are exclusive to wetlands, such as smooth cordgrass (*Spartina alterniflora*) and skunk cabbage (*Symplocarpus foetidus*), and others that also occur in terrestrial habitats (uplands), such as red maple (*Acer rubrum*) and eastern hemlock (*Tsuga canadensis*). The former plants are the best vegetative indicators of wetlands due to their strict dependence on wetlands, whereas the latter are not, by themselves, useful indicators without considering associated species or other factors. Since many wetland plant communities are comprised of plant species that also grow in uplands, it is difficult to simply determine the presence of certain wetlands by vegetation alone.

Plant ecologists have long realized that many plant species have either broad ecological tolerances that allow them to successfully establish colonies in a variety of habitats or that ecotypes have evolved that are better adapted for colonizing varying habitats (e.g., wet, dry, strongly saline, fresh, sandy, or calcareous) (Tiner, 1991a). Turesson (1922a, 1922b, 1925) aptly demonstrated the existence of ecotypes within a given species. Ecotypes are populations or groups of populations having distinct genetically based morphological and/or physiological traits. Ecotypes of a given species are usually prevented from interbreeding by ecological barriers (Barbour *et al.,* 1980). The majority of plants occurring in

Table 3 Wetland Indicator Categories of Plant Species Under Natural Conditions

Wetland indicator category	Estimated probability of occurrence in wetlands	Estimated probability of occurrence in nonwetlands
Obligate wetland (OBL)	>99%	<1%
Facultative wetland (FACW)	67–99%	1–33%
Facultative (FAC)	34–66%	34–66%
Facultative upland (FACU)	1–33%	67–99%
Upland (UPL)	<1%	>99%

wetlands have either broad ecological amplitudes or have adaptive ecotypes (see Tiner, 1991a for detailed discussion of the concept of a hydrophyte).

The first and only comprehensive lists of hydrophytes for the U.S. were compiled by the U.S. Fish and Wildlife Service with support and cooperation from three other federal agencies (Army Corps of Engineers, Environmental Protection Agency, and the Soil Conservation Service). National, regional and state lists are now available (e.g., Reed, 1988; Tiner *et al.,* 1995). These lists reference plant species that have been found in U.S. wetlands.

Given that the affinity for wetlands varies considerably among plant species, the species on these lists have been separated into four "wetland indicator categories" that reflect differences in the expected frequency of occurrence in wetlands: (1) obligate wetland (OBL), (2) facultative wetland (FACW), (3) facultative (FAC), and (4) facultative upland (FACU) (see Table 3 for definitions). The national list contains 6,728 species out of a total of approximately 22,500 vascular plant species that exist in the U.S. and its territories and possessions (Reed, 1988). Only 31% of the nation's flora occur in wetlands often enough to be recorded on the list. Thus, the majority of the nation's plant life is virtually intolerant of prolonged flooding and saturation associated with wetlands. Of those species occurring in wetlands, only 27% are OBL species (Tiner, 1991a). The majority of the listed species, therefore, grow both in wetlands and nonwetlands to varying degrees. This fact clearly complicates wetland determinations and delineations based solely on analysis of vegetation, and was probably the main reason for developing a three-parameter method for wetland identification which requires examining vegetation, soils, and hydrology. The latter approach considers plant communities dominated by OBL, FACW, and/or FAC species as positive indicators for hydrophytic vegetation. With the inclusion of FAC species, many upland (terrestrial) plant communities have a positive vegetation indicator for wetland.

The OBL and FACW species are reliable indicators of wetlands in their natural undrained condition, with the OBL species being the best indicators. OBL species are usually characteristic of the wetter (seasonally flooded to permanently flooded) wetlands, but some species, such as Nuttall Oak (*Quercus nuttallii*), may occur only at the drier end of the moisture gradient. Examples of OBL species are presented in Table 4. Some plant families or genera are exclusive to wetlands, while most have certain species that are wetland dependent. The predominance of these species or their occurrence at some level of moderate abundance should reveal the presence of wetland. Some common wetland types that can be identified

Table 4 Examples of Obligate Hydrophytes That Are Widespread or Particularly Common in Certain Wetland Types in the United States. Genera Listed Contain All or Mostly Obligates

Aquatics
Alternanthera philoxeroides (Alligatorweed), *Azolla* spp. (Mosquito-ferns), *Brasenia schreberi* (Water-Shield), *Cymodocea filiformis* (Manatee-grass), *Eichornia crassipes* (Water Hyacinth), *Elodea* spp. (Water-weeds), *Hydrocotyle ranunculoides* (Water Pennywort), *Isoetes* spp. (Quillworts), *Lemna* spp. (Duckweeds), *Limnobium spongia* (American Frog-bit), *Myriophyllum* spp. (Water-milfoils), *Najas* spp. (Naiads), *Nuphar* spp. (Pond Lilies), *Nymphaea* spp. (Water Lilies), *Proserpinaca* spp. (Mermaid-weeds), *Ruppia maritima* (Widgeon-grass), *Thalassia testudinum* (Turtle-grass), *Utricularia* spp. (Bladderworts), *Vallisneria americana* (Wild Celery), *Zannichellia palustris* (Horned Pondweed), *Zostera marina* (Eel-grass).

Emergents (Herbs)
Alisma spp. (Water-plantains), *Calla palustris* (Wild Calla), *Caltha palustris* (Marsh Marigold), *Carex aquatilis* (Water Sedge), *Carex lasiocarpa* (Woolly Sedge), *Carex stricta* (Tussock Sedge), *Cicuta maculata* (Water Hemlock), *Decodon verticillatus* (Water-willow), *Drosera* spp. (Sundews), *Dulichium arundinaceum* (Three-way Sedge), *Eleocharis* spp. (Spike-rushes), *Eriophorum* spp. (Cotton-grasses), *Glyceria* spp. (Manna Grasses), *Hibiscus moscheutos* (Rose Mallow), *Iris versicolor* (Blue Flag), *Juncus canadensis* (Canada Rush), *Juncus roemerianus* (Black Needlerush), *Kosteletzkya virginica* (Seashore Mallow), *Leersia oryzoides* (Rice Cutgrass), *Lindernia dubia* (Water Pimpernel), *Lythrum lineare* (Salt Marsh Loosestrife), *Osmunda regalis* (Royal Fern), *Peltandra virginica* (Arrow Arum), *Polygonum hydropiperoides* (Water Pepper), *Polygonum sagittatum* (Arrow-leaved Tearthumb), *Pontederia cordata* (Pickerelweed), *Sabatia stellaris* (Annual Salt Marsh Pink), *Sagittaria* spp. (Arrowheads), *Salicornia virginica* (Perennial Glasswort), *Scirpus americanus* (Olney's Three-square), *Scirpus atrovirens* (Green Bulrush), *Scirpus validus* (Soft-stemmed Bulrush), *Sium suave* (Water Parsnip), *Solidago patula* (Rough-leaved Goldenrod), *Solidago uliginosa* (Bog Goldenrod), *Spartina alterniflora* (Smooth Cordgrass), *Spartina cynosuroides* (Big Cordgrass), *Symplocarpus foetidus* (Skunk Cabbage), *Triglochin* spp. (Arrow-grasses), *Typha* spp. (Cattails), *Woodwardia virginica* (Virginia Chain Fern), *Xyris* spp. (Yellow-eyed Grasses), *Zizania aquatica* (Wild Rice), *Zizaniopsis miliacea* (Giant Cutgrass).

Shrubs
Andromeda glaucophylla (Bog Rosemary), *Batis maritima* (Saltwort), *Betula pumila* (Bog Birch), *Borrichia frutescens* (Sea Ox-eye), *Cephalanthus occidentalis* (Buttonbush), *Chamadaphne calyculata* (Leatherleaf), *Forestiera acuminata* (Swamp Privet), *Kalmia polifolia* (Bog Laurel), *Lonicera oblongifolia* (Swamp Fly-honeysuckle), *Myrica gale* (Sweet Gale), *Rosa palustris* (Swamp Rose), *Salix caroliniana* (Swamp Willow), *Salix sericea* (Silky Willow), *Vaccinium macrocarpon* (Big Cranberry).

Trees
Avicennia germinans (Black Mangrove), *Carya aquatica* (Water Hickory), *Chamaecyparis thyoides* (Atlantic White Cedar), *Fraxinus caroliniana* (Carolina Ash), *Fraxinus profunda* (Pumpkin Ash), *Gleditsia aquatica* (Water Locust), *Nyssa aquatica* (Water Gum), *Planera aquatica* (Planer-tree), *Quercus lyrata* (Overcup Oak), *Rhizophora mangle* (Red Mangrove), *Salix nigra* (Black Willow), *Taxodium distichum* (Bald Cypress).

Vines
Smilax walteri (Red-berried Greenbrier).

simply by vegetation include tidal and nontidal marshes, mangrove swamps, Atlantic white cedar swamps, pocosins, fens, sedge meadows, bogs, cypress-gum swamps, and red maple-skunk cabbage swamps.

Plant communities lacking OBL species may be dominated by hydrophytes, but these species are more wide-ranging in their habitats and the hydrophytic (wetland) populations need to be determined by proving that they are growing in water or on a substrate that is at least periodically anaerobic due to excess wetness.

For these communities, the underlying soils will usually provide this supportive evidence.

Hydric Soil Indicators

Certain soil properties typically develop under reducing soil conditions associated with prolonged inundation and/or soil saturation (Vepraskas, 1992). The presence of organic soils and gleyed soils (hydric soils) have been recently used for wetland identification and delineation (Tiner and Veneman, 1987; Environmental Laboratory, 1987; Federal Interagency Committee for Wetland Delineation, 1989; Vepraskas, 1992; U.S.D.A. Soil Conservation Service, 1994).

Organic soils (Histosols, except Folists) have formed under conditions of nearly permanent flooding and/or soil saturation. The presence of thick deposits of peat or muck, therefore, is an excellent indicator of wetlands. Such deposits are generally indicative of the wetter wetlands. The vegetation growing on such soils is often dominated by obligate hydrophytes and many of these wetlands are easily recognized by their characteristic vegetation. On other organic soil sites, OBL species, while not dominant, are usually common enough to also clearly identify these wetlands by their vegetation.

Where surface water is present for extended periods during the growing season, a shallow deposit of organic material may form on the surface of wetlands. When this layer is 8 to 16 in. thick on top of a mineral soil, it is called a "histic epipedon". It is diagnostic of a wetland and may be useful for identifying wetland plant communities dominated by FACW species or where OBL species are present but not particularly abundant. A thin layer (e.g., greater than 1 in. thick) of muck or peat on top of sandy soils is also a useful wetland indicator in many areas.

Many wetland soils in temperate regions, however, lack a mucky or peaty surface layer. These mineral soils, however, typically possess dominant low-chroma (gleyed) colors in the subsurface layer (subsoil). The presence of a gleyed subsoil (B-horizon or C-horizon) immediately below the surface layer (A-horizon) typically indicates wetland. This property is useful for identifying many drier-end wetland communities lacking OBL species. Gleyed soils are formed by reduction which mobilizes iron, thereby causing iron to be translocated out of the soil and moved to another layer, or further downslope where it may precipitate as iron oxide mottles (redox concentrations) or as iron oxides in stream water. This loss of iron and manganese is commonly called redox depletion and results in the grayish (low chroma) colors typical of hydric mineral soils (Vepraskas, 1992). Iron oxides (e.g., reddish brown, yellowish, or orange in color) may form in gleyed soils. These "high chroma mottles" or redox concentrations typically indicate a fluctuating water table and significant oxidation in the affected layer.

Gleyed soils are characteristically grayish or dull in color (see Tiner and Veneman, 1987; Tiner, 1988; Tiner, 1991c; or Vepraskas, 1992 for color photographs of gleyed soils). These low chroma colors typically indicate significant reduction in the affected soil layer (horizon). Gleyed soils may also be grayish,

Table 5 Recommended List of Primary Indicators of Wetlands in the United States. The Presence of Any of These Characteristics in an Area That Has Not Been Significantly Drained Typically Indicates Wetland. The Upper Limit of Wetland is Determined by the Point at Which None of These Indicators are Observed

Vegetation Indicators of Wetland

V1. OBL species comprise more than 50% of the abundant species of the plant community. *(An abundant species is a plant species with 20% or more areal cover in the plant community.)*

V2. OBL *and* FACW species comprise more than 50% of the abundant species of the plant community.

V3. OBL perennial species collectively represent at least 10% areal cover in the plant community and are evenly distributed throughout the community and not restricted to depressional microsites.

V4. One abundant plant species in the community has one or more of the following morphological adaptations: pneumatophores (knees), prop roots, hypertrophied lenticels, buttressed stems or trunks, and floating leaves. (*Note*: Some of these features may be of limited value in the tropics.)

V5. Surface encrustations of algae, usually blue-green algae, are materially present. (*Note*: This is a particularly useful indicator of drier wetlands in arid and semiarid regions.)

V6. The presence of significant patches of peat mosses (*Sphagnum* spp.) along the Gulf and Atlantic Coastal Plain. (*Note:* This may be useful elsewhere in the temperate zone.)

V7. The presence of a dominant groundcover of peat mosses (*Sphagnum* spp.) in boreal and subarctic regions. (Indicator species will need to be designated by regional experts.)

Soil Indicators of Wetland

S1. Organic soils (except Folists) present.

S2. Histic epipedon (e.g., organic surface layer 8–16 in. thick) present.

S3. Sulfidic material (H_2S, odor of "rotten eggs") present within 12 in. of the soil surface.

S4. Gleyed[a] (low chroma) horizon or dominant ped faces (chroma 2 or less with mottles *or* chroma 1 or less with or without mottles) present immediately (within 1 in.) below the surface layer (A- or E-horizon) *and* within 18 in. of the soil surface.

S5. Nonsandy soils with a low chroma matrix (chroma of 2 or less) within 18 in. of the soil surface *and* one of the following present above the low chroma matrix and within 12 in. of the surface:
   a. Iron and manganese concretions or nodules; or
   b. Distinct or prominent oxidized rhizospheres along several living roots; or
   c. Low chroma mottles.

S6. Sandy soils with one of the following present:
   a. Thin surface layer (1 in. or greater) of peat or muck where a leaf litter surface mat is present; or
   b. Surface layer of peat or muck of any thickness where a leaf litter surface mat is absent; or
   c. A surface layer (A-horizon) having a low chroma matrix (chroma 1 or less and value of 3 or less) greater than 4 in. thick; or
   d. Vertical organic streaking or blotchiness within 12 in. of the surface; or
   e. Easily recognized (distinct or prominent) high chroma mottles occupy at least 2% of the low chroma subsoil matrix within 12 in. of the surface; or
   f. Organic concretions within 12 in. of the surface; or
   g. Easily recognized (distinct or prominent) oxidized rhizospheres along living roots within 12 in. of the surface; or
   h. A cemented layer (orstein) within 18 in. of the soil surface.

S7. Native prairie soils with a low chroma matrix (chroma of 2 or less) within 18 in. of the soil surface *and* one of the following present:
   a. Thin surface layer (at least $^1/_4$ inch thick) of peat or muck; or
   b. Accumulation of iron (high chroma mottles, especially oxidized rhizospheres) within 12 in. of the surface; or
   c. Iron and manganese concretions within the surface layer (A-horizon, mollic epipedon); or
   d. Low chroma (gray-colored) matrix or mottles present immediately below the surface layer (A-horizon, mollic epipedon) and the crushed color is chroma 2 or less.

Soil Indicators of Wetland (continued)

S8. Remains of aquatic invertebrates are present within 12 in. of the soil surface in nontidal pothole-like depressions.

S9. Other regionally applicable, field-verifiable soil properties resulting from prolonged seasonal high water tables.

Note: Exceptions may occur as they do with any method and will be specified in the future as detected. Primary indicators for hydric prairie soils are based on field-tested recommendations by Dr. J. L. Richardson, North Dakota State University.

* Gleyed colors are low chroma colors (chroma of 2 or less in aggregated soils and chroma 1 or less in soils not aggregated; plus hues bluer than 10Y) formed by excessive soil wetness; other nongleyed low chroma soils may occur due to (1) dark-colored materials (e.g., granite and phyllites), (2) human introduction of organic materials (e.g., manure) to improve soil fertility, and (3) podzolization (natural soil leaching process in acid woodlands where a light-colored, often grayish, E-horizon or eluvial-horizon develops below the A-horizon; these uniform light gray colors are not due to wetness).

Modified from Tiner, R. W., *Wetlands,* 13:50–64, 1993. With permission.

because iron is present in its reduced form (ferrous iron, Fe^{2+}). Reduced soils may change color slightly within 30 minutes or less, upon exposure to air when ferrous iron is present (Vepraskas, 1992). They may appear more bluish at first and then change to a more dull blue-gray color. A colorimetric test using a-a diphyridal can also be used to confirm the presence of ferrous iron. Other soil properties may also be useful indicators of wetlands (see Table 5).

The U.S.D.A. Soil Conservation Service (SCS) has prepared a list of hydric soils for the country. Hydric soils are flooded, ponded, or saturated at a frequency and duration sufficient to create anaerobic conditions in the upper part of the soil (U.S.D.A. Soil Conservation Service, 1991). The intent of the definition of hydric soil was to identify soils that supported the growth of hydrophytes (Mausbach, 1994). The list of hydric soils may be useful for interpreting information in published soil survey reports, but the field indicators of hydric soil indicators are more significant and essential for wetland delineation. A list of these indicators has been published (U.S.D.A Soil Conservation Service, 1994a) and is currently being field tested. These indicators, once validated, should be extremely useful for determining the presence of wetlands in their natural, undrained conditions.

Wetland Hydrology Indicators

Certain methods for identifying wetlands require using indicators, other than vegetation and soil, to document the presence of wetland. The presence of surface water and interstitial soil water within the major portion of the plant's root zone during the growing season has been used as an indicator of wetland hydrology following federal wetland delineation methods (Environmental Laboratory, 1987; Sipple, 1988; Federal Interagency Committee for Wetland Delineation, 1989). Indirect indicators of the presence of water have also been used (Table 6). While these indicators provide evidence that an area is presently wet or that flooding or soil saturation has occurred, most fail to indicate the frequency or the duration of that event or the timing of the event. Only hydric soil properties, obligate hydrophytes, and plant morphological adaptations provide such evidence and their use

Table 6 List of Wetland Hydrology Indicators Used in U.S. Federal Wetland Delineation Manuals (CE - Corps of Engineers Manual, EPA - Environmental Protection Agency Manual, FICWD - Federal Interagency Committee for Wetland Delineation Manual)

Hydrology indicator	Manuals
Inundation during growing season	CE, EPA, FICWD
Soil saturation within 12″ of the surface during growing season	CE, EPA, FICWD
Water marks	CE, EPA, FICWD
Drift lines	CE, EPA, FICWD
Water-borne sediment deposits	CE, EPA, FICWD
Drainage patterns within wetlands	CE, FICWD
Hydrology data from published soil survey reports (after verifying soil type)	EPA
Surface scoured areas (includes bare areas subject to prolonged inundation)	EPA, FICWD
Moss lines on trees and shrubs	EPA
Morphological plant adaptations to inundation/soil saturation[a]	EPA, FICWD
Oxidized rhizospheres along living roots and rhizomes[b]	FICWD
Water-stained leaves	FICWD
Hydric soil characteristics (in areas with no apparent significant hydrologic modification - drainage)	FICWD

[a] CE manual considers these as indicators of hydrophytic vegetation.

[b] EPA manual considers these as indicators of hydric soil.

is limited to hydrologically unaltered sites. Despite these limitations, all of these hydrologic indicators have been used to verify that an area or plant community is presently subjected to wetland hydrological conditions following federal wetland delineation procedures.

METHODS TO IDENTIFY AND DELINEATE WETLANDS

A host of techniques have been developed to identify and delineate wetlands subject to government regulations. Certain agencies have conducted mapping projects to locate these areas, while others have developed methods to be employed on-the-ground to identify regulated wetlands. These approaches are briefly described in the following subsections.

Field Delineation Techniques

Four basic methods have been used for identifying and delineating wetlands in the field: (1) vegetation-based techniques, (2) soil-based methods, (3) three-parameter methods, and (4) the primary indicators method. Each of these approaches is briefly discussed below; for more detailed reviews, see Tiner (1989, 1993a, 1993b).

Vegetation-Based Methods

Vegetation-based methods require analysis of the plant community to identify regulated wetlands. These methods were the earliest techniques used to determine the jurisdictional limits of state wetland regulations. These methods were probably developed due to the involvement of botanists and wetland ecologists in creating wetland laws and the existence of much published technical and nontechnical botanical information, including field guides for plant identification on wetlands.

A "50% rule" was commonly employed to establish the predominance of wetland plants. Wetlands were identified where more than 50% of the plants were wetland species. This approach probably worked well for identifying salt marshes and the wetter freshwater nontidal wetlands where OBL and FACW species predominate, but it was less useful for identifying drier-end wetlands and wetland boundaries in areas of low relief.

Major shortcomings of this method include the lack of a comprehensive list of wetland plants and standardized methods for assessing the vegetation. The latter could have been easily resolved, since there are numerous techniques available for performing quantitative assessments of vegetation patterns in the published literature on plant ecology. The former shortcoming has been recently overcome by the development of national, regional, and state lists of plant species that occur in wetlands by the U.S. Fish and Wildlife Service (FWS). Despite these developments, there remain serious obstacles to using plants alone to identify wetlands: (1) the species level of plant taxonomy is not adequate for identifying wetland ecotypes (hydrophytes) of species that occupy both wetland and upland habitats, (2) many species growing in wetlands have broad ecological tolerances and are also associated with and even dominant in drylands, and (3) many wetland communities lack OBL species. As a result, any attempt to rely solely on vegetation for identifying wetlands will either fail to recognize all wetlands (error by omission) or will include nonwetlands as wetland (error by commission).

Soil-Based Methods

Soil-based methods rely on the presence of certain soil properties (e.g., hydric soils) to designate wetlands. These methods have not been widely used, probably due to little input from soil scientists in the wetland protection and regulatory process and a general lack of published material describing the utility of soils for identifying and delineating wetlands. In Connecticut and New Hampshire, soil scientists have contributed significantly to the development of state and local wetland protection programs and, as a result, soils are used to identify wetlands at the state level in Connecticut and in many municipalities with local wetland zoning ordinances in New Hampshire. Connecticut considers all poorly drained, very poorly drained, alluvial, and floodplain soils as wetlands (Table 1). This approach includes areas of nonhydric soils on floodplains as "wetland", which makes it more expansive than the conventional concept of wetland.

Some limitations of relying solely on hydric soil properties to designate wetlands include: (1) current techniques require considerable technical expertise in soil taxonomy in order to use; (2) the lack of "field guides" to aid and standardize hydric soil/wetland determinations presently leads to varied interpretations, especially in drier-end wetlands and at the wetland border in low-gradient systems; (3) the need to separate effectively drained hydric soils from other hydric soils since soil morphology usually does not significantly change; and (4) recognition that many types of hydric soils lack distinguishing morphologic properties for separating them from nonhydric soils without considering other factors (e.g., vegetation). The development of "Field Indicators of Hydric Soils of the United States" (U.S.D.A. Soil Conservation Service, 1994a) is the federal government's first attempt at standardizing hydric soil determinations through the use of field indicators. After field testing and verification, these verification indicators coupled with regional field guides illustrating these properties (e.g., Tiner and Veneman, 1987) could greatly facilitate the use of soils for wetland determinations by non-soil scientists as well as providing consistent interpretations by soil scientists.

Three-Parameter Methods

Three-parameter methods typically require verifying the presence of hydrophytic vegetation, hydric soils, and wetland hydrology to identify and delineate wetlands. The federal government developed this approach to identify wetlands subject to regulation under the Federal Clean Water Act. Three manuals using this type of approach have been developed; one by the Corps of Engineers (CE) (Environmental Laboratory, 1987), another by the Environmental Protection Agency (EPA) (Sipple, 1988), and a third by an interagency committee representing CE, EPA, FWS, and SCS (Federal Interagency Committee for Wetland Delineation, 1989). The first two manuals were prepared solely for identifying federally regulated wetlands, while the latter manual was developed for a broader purpose, including but not limited to wetlands potentially subject to federal regulation.

The 1989 interagency manual is intended to develop a standard scientifically based method to identify all vegetated wetlands in the U.S., regardless of their values or current regulatory programs and government policies. It was perceived that such a document would have broad utility and could be adopted by states and local governments interested in wetland protection and regulation independent of that implemented by the federal government. Subsequently, several states (e.g., New Hampshire, Maine, and Pennsylvania) adopted this manual for their state regulatory programs.

While all three manuals require making observations of vegetation, soils, and hydrology, the CE manual essentially requires finding positive indicators of all three parameters (hydrophytic vegetation, hydric soils, and wetland hydrology) for wetland identification and delineation (Environmental Laboratory, 1987). Tiner (1993b) provides an overview of this manual and mentions some of its limitations.

The EPA manual (Sipple, 1988) and the 1989 manual (Federal Interagency Committee for Wetland Delineation, 1989) both require consideration of all three parameters, but in many cases would accept less than three indicators as necessary for a wetland determination. For example, if a plant community satisfied both the hydrophytic vegetation and hydric soil criteria and no field indicators of wetland hydrology were present, the 1989 manual considered this area as wetland *provided it was not hydrologically altered* (e.g., drained). In this case, the vegetation and soils were deemed sufficient to make a wetland determination. Three-parameter fundamentalists criticized this protocol.

Some shortcomings of the three-parameter approaches include: (1) time required to perform wetland delineations, (2) the need to find positive indicators of wetland hydrology for hydrologically unmodified sites dominated by hydrophytic vegetation growing on hydric soils (CE manual), (3) applying one wetland hydrology standard to all wetlands, (4) the questionable strength and significance of some of the wetland hydrology indicators (e.g., drift lines, water marks, and "wetland" drainage patterns), (5) the use of nonstandard terms and concepts (e.g., drainage classes) in the hydric soil criterion, (6) too much reliance on professional judgment and room for individual interpretation or bias (CE manual), and (7) use of FAC species as indicators of hydrophytic vegetation.

Primary Indicators Method

The primary indicators method (PRIMET) is an outgrowth of traditional methods of identifying wetlands (Tiner, 1993a). It attempts to use vegetation patterns, soil properties, and other features that are unique to wetlands as diagnostic for wetland identification and delineation. The basic premise is that in the absence of significant hydrologic modification, these unique features can be reliably used to make wetland determinations. It further recognizes that significantly hydrologically altered sites require an assessment of the current hydrology because the preexisting soil and vegetation characteristics are persistent in most cases, and are no longer useful indicators of wetlands in such disturbed sites. Florida and Rhode Island have adopted this type of method for identifying regulated wetlands (Matthews, 1994).

Wetlands and their boundaries are defined by the presence of any one of numerous primary indicators (see Table 5 for examples). This approach is a rapid assessment technique which permits wetland determinations to be made with minimal investment of time. In doing so, it does not require detailed documentation of plant communities or soil characteristics. Also, proper use of the method requires that an initial evaluation of potential hydrologic modification be performed. Protocols for doing such evaluation need to be developed. Standardized procedures for handling hydrologically altered sites need to be developed, but this is true for all methods in current use. The PRIMET does, however, recognize that wetland hydrology requirements differ among wetland types and need to be considered when evaluating significantly drained sites.

Wetland Mapping

Wetland maps provide information on the location, type, and distribution of wetlands in a format that is available to and readily understood by the general public. It requires an enormous effort on behalf of the government, but it has the distinct advantage of showing people where these areas are located. Interested people can, therefore, determine the presence or absence of wetlands on their properties and get a good idea of the general location of these potentially regulated areas. Similar mapping has been done throughout the U.S. when private land is zoned for specific purposes (e.g., town zoning maps).

It must be readily acknowledged that wetland mapping is not as accurate as field delineation of wetland boundaries. Yet, conventional wetland mapping techniques (i.e., photointerpretation), combined with extensive field work to verify the maps, may be capable of producing a product that identifies the spatial extent of wetlands to the degree necessary to preserve the wetland ecosystem functions that the regulating agencies are interested in protecting. Aerial photographs of some wetlands (e.g., certain evergreen forested wetlands) are difficult to interpret (Tiner, 1990) and these wetlands may have to be addressed by other means, whereas most marshes, swamps, fens, and bogs are readily photointerpreted. Field verification of wetland boundaries for assessing site-specific project impacts will still, however, be necessary to establish the line on the ground where projects are encroaching on wetlands.

Wetland maps are produced through remote sensing techniques in two main ways: (1) photointerpretation of aerial photos, and (2) satellite image processing. Although satellite technology is improving, it is still not capable of producing as accurate and detailed wetland inventories as prepared through conventional photointerpretation techniques. The Federal Geographic Data Committee (1992) recently reached this conclusion in their report "Application of Satellite Data for Mapping and Monitoring Wetlands — Fact Finding Report". Most large-scale wetland inventories have used or are utilizing aerial photointerpretation techniques to produce wetland maps.

Several states have produced maps of regulated wetlands. The states of Connecticut, New Jersey, New York, Delaware, and Maryland have produced such maps for coastal wetlands (salt and brackish water marshes, and other tidal wetlands). These wetlands are among the most easily recognized through photointerpretation. New York has produced statewide inland wetland maps that show designated regulated wetlands.

Other states and the federal government have conducted wetland inventories and produced wetland maps. These maps do not identify the limits of government jurisdiction, but do show areas where permits may be required. For the most part, these maps are conservative in the identification of wetlands, with limited field work performed.

The most readily available wetland maps for the United States are National Wetlands Inventory (NWI) maps produced by the U.S. Fish and Wildlife Service (Figure 1). The NWI mapping techniques involve: (1) stereoscopic photointerpretation

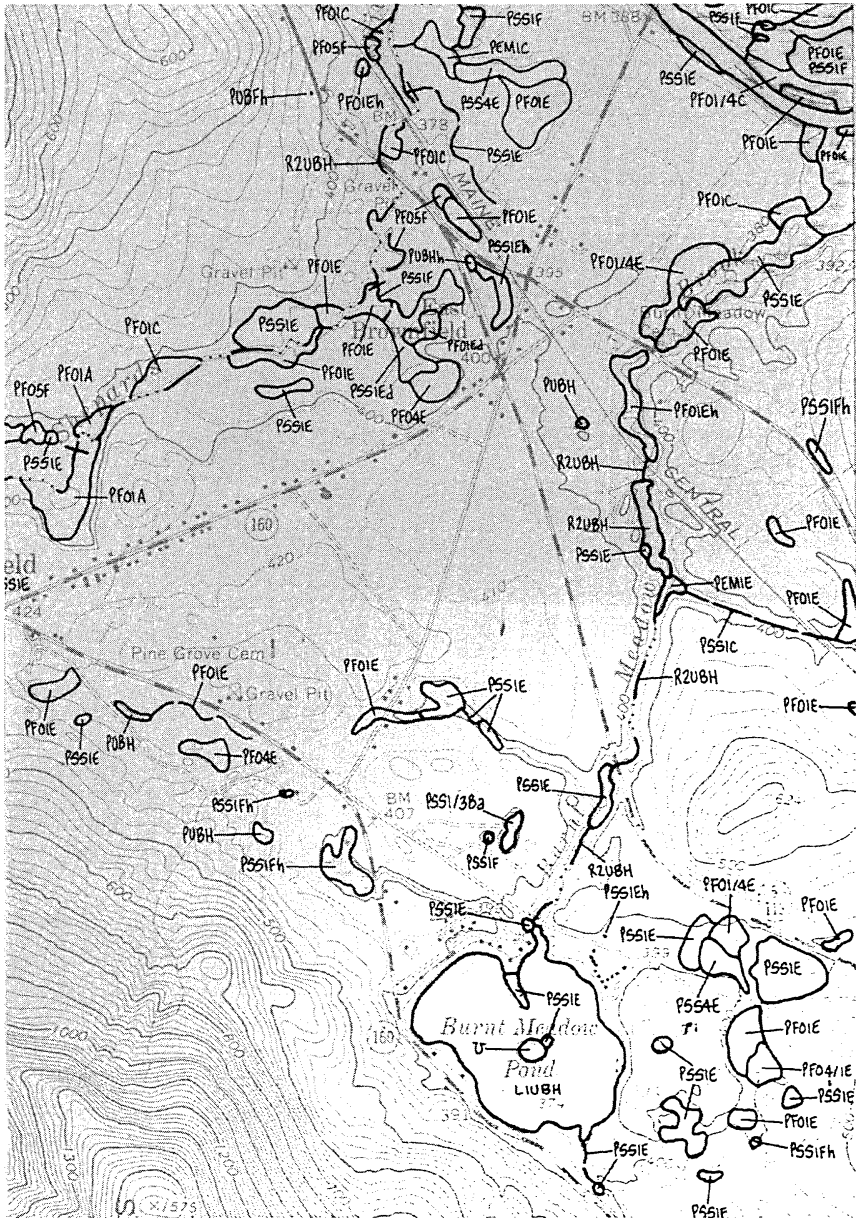

Figure 1 Example of a portion of the National Wetlands Inventory map for Brownfield, Maine (scale 1:24,000). Alpha-numeric codes represent different wetland and deepwater habitats, e.g., forested wetlands (PFO1E, PFO1/4C, PFO4E, PFO1A, etc.), scrub-shrub wetlands (PSS1E, PSS1F, PSS4E, PSS1/3Ba), emergent wetlands (PEM1E), ponds (PUBHh, PUBFh), lakes (L1UBH), and rivers (R2UBH). Minimum mapping unit is 1–3 acres, since 1:58,000 aerial photos were interpreted for this area.

of high- to medium-altitude aerial photography, (2) selective ground truthing, (3) review of existing information, (4) conventional cartographic procedures to produce a series of 1:24,000 maps, and (5) digital map database construction. U.S. Geological Survey topographic maps serve as the base maps for displaying wetlands inventory data. Minimum mapping units (mmu) of designated wetlands vary depending largely on the scale of the photographs used for wetland interpretation: 3–5 acres (1:80,000), 1–3 acres (1:58,000), and 1 acre (1:40,000). Certain conspicuous wetlands (e.g., prairie pothole marshes) and ponds smaller than the mmu may be shown. The wetlands which are more difficult to interpret from air photos (e.g., evergreen forested wetlands and seasonally saturated meadows and swamps) may be missed or conservatively mapped. In most areas, minimal field verification has been performed, so wetland mapping is conservative. More recently, however, use of 1:40,000 color infrared photography combined with extensive field verification have greatly improved the comprehensiveness and accuracy of the mapping.

The State of Maryland is on the cutting edge of wetland mapping technology. The Water Resources Administration is producing digital wetland maps at 1:7200 scale on orthophoto base images (Burgess, 1993). The maps do not show the boundaries of state-regulated wetlands, since Maryland requires site-specific wetland delineation for proposed projects. Instead, the maps are used as regulatory guidance maps showing the general limits of wetlands potentially subject to regulation. These maps are perhaps the most detailed and spatially accurate of any wetland maps produced to date for a large geographic area. Their mapping technique involves several steps: (1) stereoscopic photointerpretation of 1:40,000 color infrared aerial photography following NWI conventions, (2) extensive field verification, (3) vectorization of photointerpreted data (conversion to digital file), and (4) creation of digital orthophoto quarter/quad wetland maps. Figure 2 shows an example of a portion of one of these maps. The costs of this effort for Maryland is estimated at $4.5 million, which seems too expensive for most states and the nation as a whole. Yet, much of this cost is for producing base maps (orthophoto quarter-quads) and not for the compilation of wetland data. The base maps serve many purposes besides the wetland mapping, so the real cost of the wetland mapping is considerably less. Cooperative federal-state projects to produce orthophoto quarter-quads will further reduce costs for participating agencies. The U.S. Geological Survey is actively seeking cooperators for such projects.

DISCUSSION

Wetland maps have played and continue to play an important role in wetland protection. Many states have produced maps showing the location of regulated coastal wetlands, but few states have ventured to do this for inland wetlands. Wetland mapping has many advantages over field delineation from the standpoint of the regulated community. Most importantly, such maps could show the extent of government jurisdiction in a medium easily understood by most people. Presently,

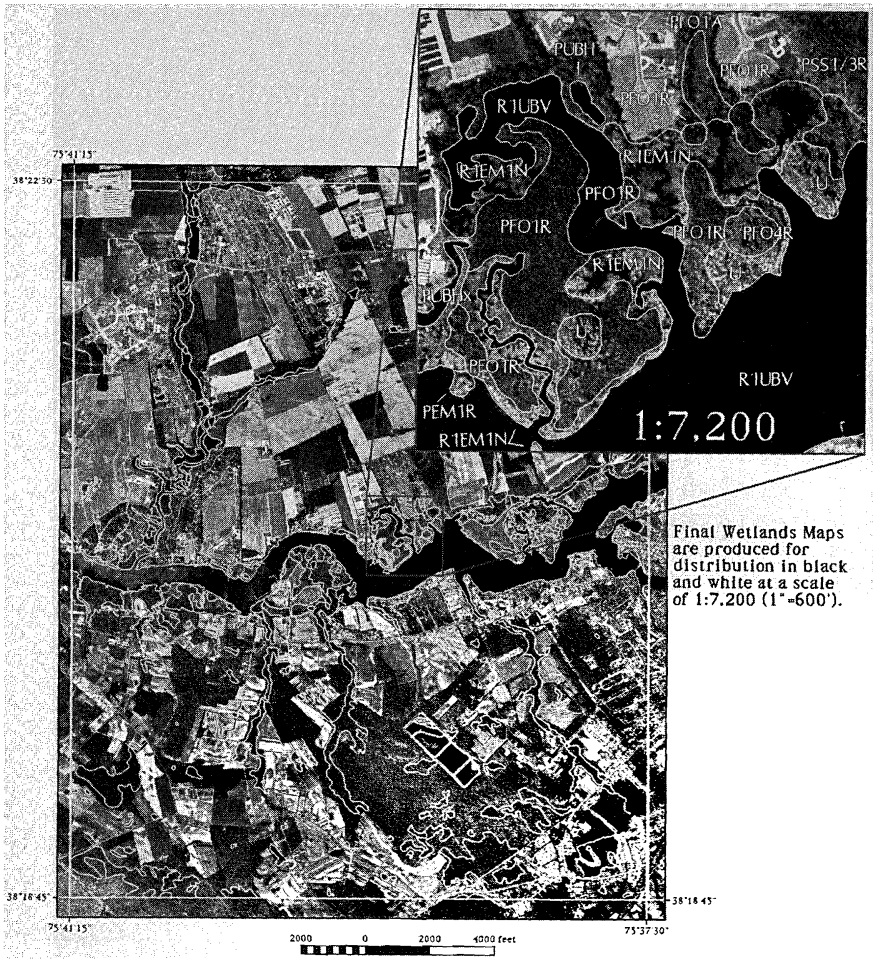

Figure 2 Example of a state regulatory guidance wetland map (produced on a digital orthophoto quarter quad base) for Maryland. Alphanumeric codes for wetlands and deepwater habitats follow the U.S. Fish and Wildlife Service's wetland classification system.

the public in many areas must hire an environmental consultant to determine the limits of government jurisdiction (i.e., wetlands) on their property.

Despite these rather obvious advantages, why have not all regulatory agencies produced wetland maps? Wetland mapping can be expensive. To produce a set of regulatory maps similar to NWI maps, but with specially flown aerial photography, extensive field verification, and improved accuracy could cost an estimated $500 million to cover the entire U.S. (Don Woodard, U.S. Fish and Wildlife Service, personal communication). Yet, if one really considers the cost of the existing federal regulatory program, the cost of this mapping effort is not

unthinkable in terms of the federal budget, especially when the cost is spread out over a number of years. The greatest concerns with wetland mapping probably are the limitations of remote sensing techniques for detecting and mapping all wetlands and that such techniques cannot delineate wetlands as well as a trained specialist can on the ground. Certain evergreen forested wetlands and drier-end wetlands (seasonally saturated and/or temporarily flooded) are difficult to identify and accurately delineate through remote sensing. Extensive field verification and consultation of existing data such as soil survey reports may, however, help overcome most of these technical problems. Regardless, any mapping effort will miss some wetlands, since by convention there is a minimum size limit that can effectively be shown on a map of a certain scale. Technical constraints and minimum mapping units will invariably result in the omission of some wetlands. Some key questions are (1) What types of wetlands are being missed? (2) What percent of the total wetland resource do they represent? (3) Are these wetlands vital to preserving the wetland functions and values that society desires and is interested in protecting? (4) If so, does this eliminate or greatly diminish the value of regulatory maps? and (5) Can maps be used to show the boundaries of, at least, certain wetland types that are readily identified through remote sensing techniques? The answers to these and other questions will largely determine the utility of maps for wetland regulation.

Given current remote sensing technologies and other available information (e.g., soil surveys), it is possible to produce a set of regulatory maps showing the location of water bodies, wetlands that are amenable to air photo interpretation, and well-defined nonwetlands (uplands), with the remaining lands designated as areas requiring field inspection to identify wetlands. The latter areas may be identified by considering landscape positions that favor wetland establishment and by consulting existing soil survey data. By separating "land" into three categories (wetland, upland, and land requiring field inspection), the geographic scope of potentially regulated land would be defined on a set of maps. Thus, the public would be duly informed of jurisdictional limits. Individuals looking for the most readily developable lands could simply consult the maps for optional parcels. This could result in a significant improvement in the efficiency of current wetland regulatory programs, in part by helping guide development away from wetlands to more suitable sites.

Mapping does not preclude the need for on-site inspections. Even where regulatory maps are produced, field delineation is still required to establish a line on the ground to guide landowners on where permits are necessary for work and where they are not, especially when projects are planned for construction in the wetland or near its border.

Standardization of field methods is needed to ensure accurate identification of wetlands and their boundaries. Such methods should be (1) technically sound by making use of current scientific knowledge to accurately identify wetlands, as well as being legally defensible (rather than being arbitrary and capricious); (2) precise enough to produce repeatable results so that different investigators would identify essentially the same boundary for a given wetland regardless of the time

of year of field inspection; (3) practical and easy to use, emphasizing relatively easily observed features that can be recognized by generalists in major biological and physical sciences and not require highly specialized technical expertise to implement; (4) efficient — requiring only minimal effort to identify the wetter wetlands and increased effort for more difficult-to-identify wetlands; (5) capable of producing most determinations in a single site inspection; (6) able to permit wetland identification throughout the year (except perhaps when the soil is frozen and the area is snow covered); (7) sufficient in scope to encompass regional variation in wetlands throughout the United States; and (8) flexible enough to allow for limited use of professional judgment in difficult or confounding situations (Tiner, 1993a). Without standard methods and well-trained personnel to employ them, wetland identification and delineation would be extremely varied among individuals engaged in such tasks. This would pose a consistency problem for regulators and the regulated community alike. Moreover, it would further jeopardize protection of wetlands and their functions by failing to include them in the regulatory review process. Development of standardized wetland delineation methods and providing training to potential users are vital to the success of any wetland regulatory program.

In creating standard procedures for wetland delineation, the limitations of our knowledge of wetlands quickly become evident when considering wetland hydrology. The wetland paradox is that despite a wealth of information about wetlands, we do not know how wet a wetland is at its upper limit, or in other words, the minimum wetness required to create wetlands. There are no long-term studies of water table fluctuations along the soil moisture gradient between wetlands and uplands. Only recently have short-term studies been initiated (e.g., Allen *et al.*, 1989; Anderson *et al.*, 1980; Carter *et al.*, 1994; Roman *et al.*, 1985; Veneman and Tiner, 1990). This should not be construed as suggesting that we know nothing about wetland hydrology. Most, if not all, wetland ecologists would agree that an area flooded for a month or more during the growing season of each year is wet enough to support hydrophytes and be classified as wetland. Yet, is one week of flooding every other year sufficient for wetland establishment? Must wetlands be saturated to the surface for long periods and if so, how long, how often, and during what season? Is prolonged wetness during the "growing season" the most significant process affecting plant communities and wetland functions? How long does it take for soils to develop hydric properties? There are many other unanswered questions about wetland hydrology. Requiring verification of wetland hydrology for natural, undisturbed wetlands is unnecessarily burdensome and puts too much emphasis on a condition that is not well documented in the scientific literature (Environmental Defense Fund and World Wildlife Fund, 1992; Tiner, 1991b). Existing wetland definitions reflect this and do not mention specific time periods for inundation or soil saturation. Consequently, wetland identification has traditionally centered on plants and soils. These features are still the most useful indicators of wetlands in areas not significantly drained (Carter *et al.*, 1994; Federal Interagency Committee for Wetland Delineation, 1989; Sipple, 1985; Tiner, 1993a). As long as on-the-ground delineations are required, field

indicators of wetland will be used for wetland identification and boundary delineation at sites with unaltered hydrology. While additional investigations are needed to corroborate use of certain indicators, there is little practical value to requiring a specific hydrology for natural wetlands in terms of days of flooding and/or soil saturation, given the absence of site-specific hydrologic data at most sites and a general lack of knowledge about the variations in hydrology between different wetland types and among similar types throughout the country.

Why then has there been so much recent attention in the U.S. placed on defining wetlands in terms of days of inundation and/or soil saturation? The need for this information stems from government regulatory programs that place certain restrictions on the use of wetlands on private property and the fact that many areas have experienced significant hydrologic modification through drainage ditches, tile drains, ground water withdrawals, river diversions, or other actions. In these highly disturbed areas, plant communities and soil properties are less reliable indicators of wetland, since they generally reflect previous hydrology. This is especially true of soils, which typically represent the best expression of long-term hydrology. Plants are more responsive to changing hydrologic conditions. A change in vegetation may indeed indicate altered hydrology (drainage), but the degree of the modification is usually not easily determined by vegetative analysis. Where UPL species have become dominant, there should be widespread agreement that the wetland is now effectively drained. Yet, in most cases, this does not happen, but instead, FACU species that occur in natural wetlands such as black cherry (*Prunus serotina*), may be establishing themselves, while most of the preexisting plant community remains, being able to tolerate the more mesic conditions created by drainage. The increase in these types of species is not definitive in determining the extent or effectiveness of drainage.

In sites with significantly altered hydrology, the current hydrology needs to be determined. This can be accomplished in several ways ranging from conducting on-site ground water well studies and interpreting stream gauge data (for floodplain sites) to modeling studies for determining the scope and effect of ditches and tile drains. The U.S.D.A. Soil Conservation Service has prepared a handbook to aid in determining wetland hydrology (U.S.D.A. Soil Conservation Service, 1994b). This manual is undergoing peer review and field testing.

Consideration and evaluation of the frequency and duration of flooding and soil saturation should be restricted to sites whose hydrology appears to be significantly altered (e.g., extensive drainage). For these situations, a minimum threshold of wetland hydrology needs to be developed to aid regulators in determining areas wet enough to potentially regulate. This threshold should vary according to the wetland type (region, climate, physiography, topography, etc.), since the minimum wetness for a prairie pothole wetland in the Upper Midwest should be different than that of a bog or a tidal marsh due to differing hydrologies. Compiling the best available information from the literature, with review by leading wetland scientists in each region, should allow reasonable and practical minimum standards to be developed. Again, such standards should be applied only to significantly disturbed sites and not to more natural wetlands or wetlands with minor drainage (e.g., a single ditch through a large wetland). Soil and vegetation

indicators are reliable for identifying the latter wetlands. Regional committees, including federal and state wetland experts, could be established to expand the list of primary indicators for the variety of wetlands occurring in each region. The Primary Indicators Method provides the most practical and expeditious approach to identifying these wetlands. With delineation performed quickly and efficiently, investigators can then put more effort towards functional analysis of wetlands relative to the proposed alterations.

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